

## IGNITION OF HOMOLOGICAL SERIES OF HYDROCARBONS BY VOLUME NANOSECOND DISCHARGE

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The experimental setup to investigate ignition of hydrocarbon-oxygen mixtures includes a shock tube combined with a nanosecond high voltage generator. The tube allows one to get temperatures in the range of 700-2500 K. Gas parameters behind the reflected shock wave are calculated from the velocity of the shock wave, which is measured by the Schlieren system. The dielectric end-section of the shock tube with 2.5x2.5 rectangular channel 20 cm long is used as a discharge cell. The end plate of the shock tube serves as a high-voltage electrode, and the discharge closes on the stainless steel part of the shock tube. Ignition delay of the combustible mixture is determined as a sharp increase of an OH emission at 306 nm and/or CH emission at 431 nm. In order to measure energy input electrical parameters (voltage and current) of the discharge are monitored with a nanosecond resolution by means of magnetic current gauge and capacitance gauges. To study the spatial structure of the discharge and the uniformity of ignition and combustion, we carried out an additional series of experiments, in which the emission intensity (integrated over the wavelength range 300-800 nm) was measured with a PicoStar HR12 ICCD camera. The discharge produces a lot of species: electronically excited atoms and molecules, ionized particles, vibrationally excited components.

To elucidate the role of atoms and electronically excited species we have performed experiments with ignition initiation by the ArF laser at the same experimental conditions as the ignition by the discharge. Laser flash was organized with a controlled delay behind the reflected shock wave at the controlled shock wave velocity and initial gas pressure. These parameters allowed us to calculate a gas temperature ( $T_5$ ) and a pressure ( $P_5$ ) behind the reflected shock wave. Some delay of the ignition was determined from OH emission, like in the case with auto-ignition and ignition by the discharge. We used a PEM21 calibrated piezoelectric detector to measure energy input from laser radiation into the gas.

To investigate slow alkanes oxidation under nanosecond pulse-periodic discharge in stoichiometric and lean mixtures with air and  $O_2$  the discharge was initiated in the tube by negative polarity pulses with the amplitude 11 kV, 25 ns duration and 5 ns rise time and 40 Hz repetition rate. The discharge cell was made of a screened quartz tube with the inner diameter of 47 mm and outer – 50 mm. The low-voltage electrode was connected to the screen. The distance from the edge of a high-voltage electrode to a low-voltage electrode was 200 mm. The system of electrical parameters diagnostics consisted of a back current shunt mounted in the screen of the cable and the mobile capacitive gauge under the screen of the cell. The emission intensity of set of molecular transitions was measured in time-resolved and integral regimes. Time-resolved measurements were used to obtain lifetime and quenching constants for the emission states and to separate crossed bands. Measurements of integral emission allowed one to obtain a full oxidation time. Emission passed through the 30 mm diameter  $CaF_2$  window in the ring low-voltage electrode. In the methane containing mixtures absorption of He-Ne laser emission at  $\lambda=3.3922 \mu m$  was measured. All time-resolved (nanosecond) measurements were executed at the beginning of discharge and after oxidation process finished in the regime of 128 pulses averaging. The density of  $H_2O_2$  was controlled using absorption in the UV region of the spectrum (at 210 nm). The kinetic scheme was proposed to describe kinetic peculiarities of oxidation in the low-temperature region.

The investigation of efficiency of the nanosecond discharge to ignite a homological family of hydrocarbons has been started. Stoichiometric gas mixtures of methane, propane, butane and pentane diluted with Ar (10% of the mixture : 90% of Ar) have been investigated under the same experimental conditions. To initiate the ignition nanosecond discharge of 110 kV (negative polarity) and 40 ns duration has been used. It is demonstrated that high-voltage nanosecond discharge is an efficient tool of ignition of different hydrocarbons. Results for the ignition delay and shift of a temperature

threshold under the action of nanosecond discharge have been obtained experimentally and compared with maximal possible temperature shift for the case when all the energy from discharge goes to gas heating. It allows one to demonstrate the efficiency of nonequilibrium plasma in a problem of ignition. Calculations of the delay time for auto-ignition were performed and compared with experimental data.

The role of different species in the ignition process has been analyzed. To do that, we carried out experiments, in which nanosecond gas discharge was replaced by flash-photolysis from an excimer ArF laser at a wavelength of 193 nm. Mixtures of a special composition ( $N_2O:H_2:O_2$  in different proportions diluted with Ar) were used to elucidate the role of atomic oxygen in the  $O(^1D)$  state.

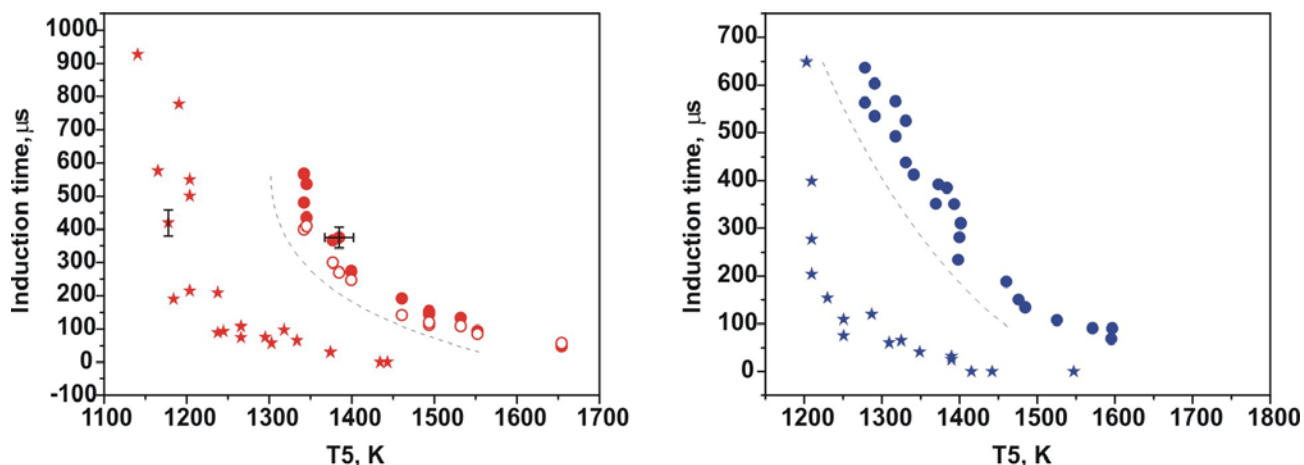


Fig. 1. Typical behavior of the ignition delay shift for  $C_4H_{10}$  (left plot) and  $C_5H_{10}$  (right plot). Mixtures contained 10% of stoichiometric hydrocarbon-oxygen mixture diluted with Ar (90%). Filled circles correspond to auto-ignition, empty circles – calculation, stars – ignition by nanosecond discharge. Dashed line demonstrates a maximal possible shift for the case when all the energy of the electric pulse goes into heat

Slow oxidation of  $C_2H_2$ ,  $CH_3COCH_3$  and  $C_2H_5OH$  in stoichiometric and some lean mixtures with oxygen under the action of the nanosecond pulsed-periodic discharge has been investigated experimentally. CO oxidation under the action of the discharge in the stoichiometric mixture with  $O_2$  in the presence of small additions of  $H_2$  has been investigated experimentally.

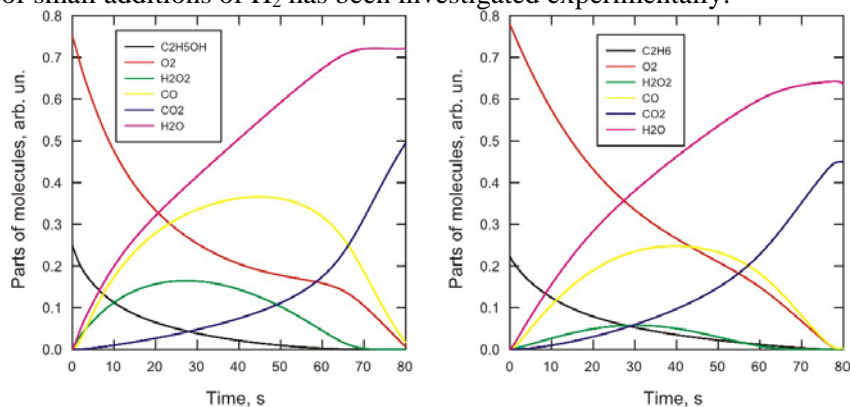


Fig. 2. Example of the calculated parts of the molecules during the oxidation process of  $C_2H_5OH$  and  $C_2H_6$  in stoichiometric mixtures with oxygen. The initial pressure of the mixture is 6.8 torr. Dissociation degrees correspond to 70% of the experimentally measured energy input in the discharge

The kinetics of slow oxidation of  $H_2$ ,  $CH_4$ ,  $C_2H_6$ ,  $C_2H_5OH$ ,  $C_2H_2$ ,  $CH_3COCH_3$  under the action of the nanosecond pulsed-periodic discharge in mixtures with oxygen at room temperature under nanosecond uniform discharge have been considered. The important role of  $O(^1D)$  and OH-radical has been determined in the kinetics. Main paths of radicals and atoms creation in the discharge have been shown. The kinetic scheme for the  $H_2$ ,  $CH_4$ ,  $C_2H_6$  and  $C_2H_5OH$  oxidation at room temperature under the nanosecond discharge action has been developed. Measurements of the  $H_2O_2$  behavior at different regimes have been performed to validate the proposed scheme. The results of calculation using this scheme are in a good agreement with experimental results.